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Are the extremely hot O and N plasmas the debris-less soft X-ray light source ?

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Contents of this talk

- Motivation – What's SWCX ?
- Features of CX of multiply charged ions
- Principle of the measurements
- Preliminary results
- Proposal

Solar Wind = extremely thin plasma

- Negative : $\mathbf{e^-}$ ~ 10 cm^{-3} around the Earth
- Positive : $\mathbf{H^+}$ ~ 90%

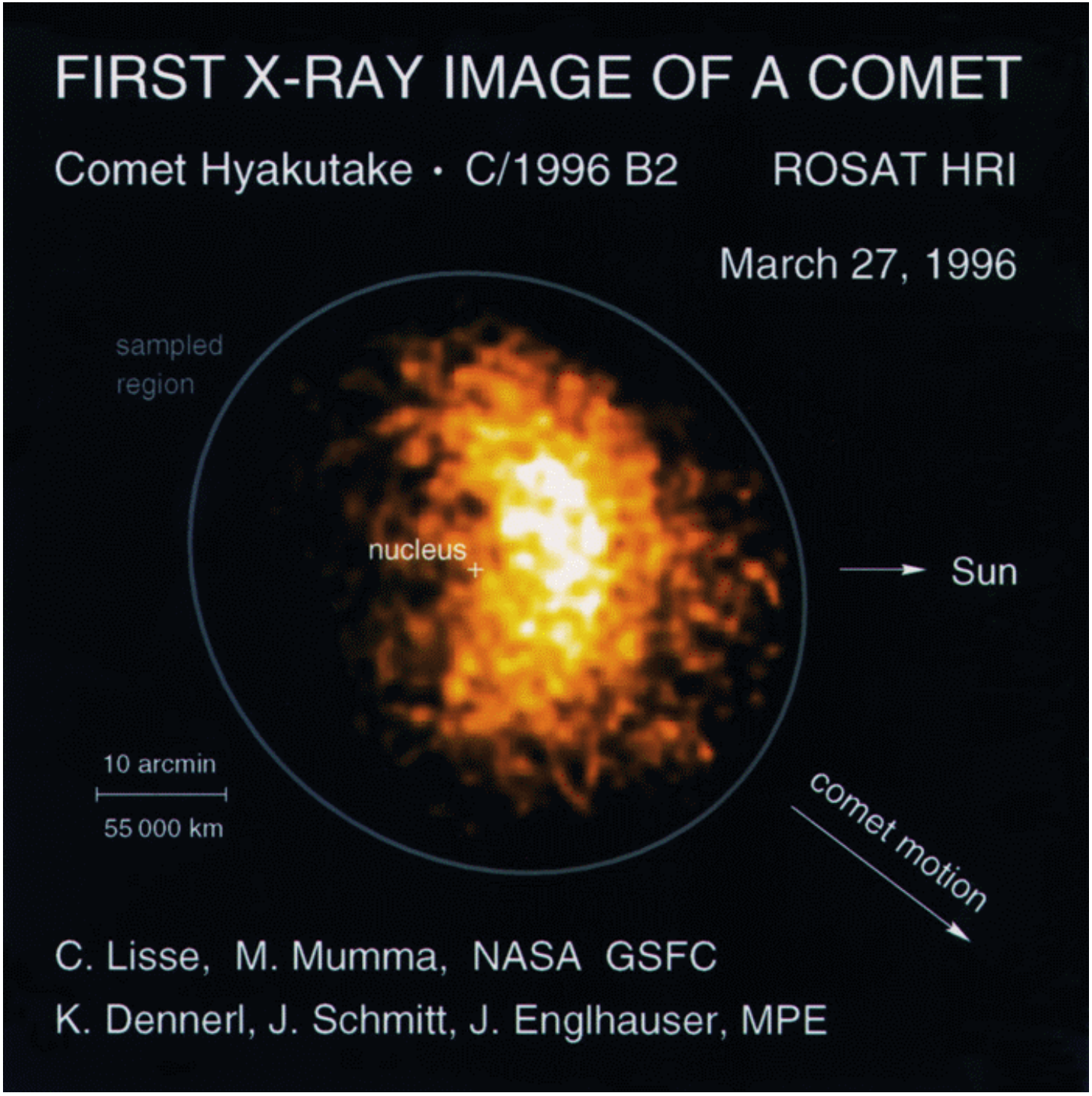
  $\mathbf{He^{2+}}$ ~ 5%

  $\mathbf{C^{q+}}$, $\mathbf{N^{q+}}$, $\mathbf{O^{q+}}$, $\mathbf{Ne^{q+}}$, $\mathbf{Mg^{q+}}$, $\mathbf{S^{q+}}$, *etc.*
- Velocity : 200-400 km/s, 700-900 km/s

Solar-Wind Charge-eXchange X-ray emission

$$O^{7+}(1s) + H \rightarrow O^{6+}(1snl) + H^+$$

$$\rightarrow O^{6+}(1s^2) + h\nu \ (\geq 561 eV)$$


FIRST X-RAY IMAGE OF A COMET
Comet Hyakutake · C/1996 B2
ROSAT HRI
March 27, 1996
sampled region
nucleus
Sun
10 arcmin
55 000 km
comet motion
C. Lisse, M. Mumma, NASA GSFC
K. Dennerl, J. Schmitt, J. Englhauser, MPE

Science
AAAS

X-ray Emission from Comets

T. E. Cravens, *et al.*

Science **296**, 1042 (2002);
DOI: 10.1126/science.1070001

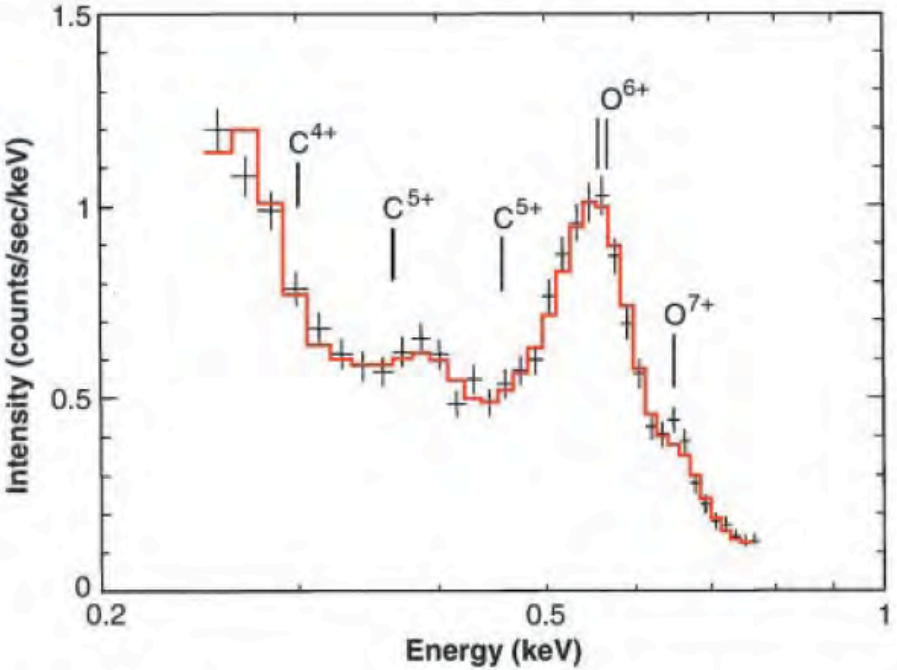


Fig. 2. Intensity versus photon energy. Soft x-ray spectrum of comet C/LINEAR 1999 S4 obtained on July 14, 2000, by the Chandra X-ray Observatory ACIS-S instrument. The solid red line is from a six-line best-fit "model" in which the line positions were fit parameters. The observational full-width half-maximum energy resolution was $\Delta E = .11$ keV. The positions of several transition lines from multiply charged ions known to be present in the solar wind are indicated but were not part of the data fit. Adapted from (*22*).

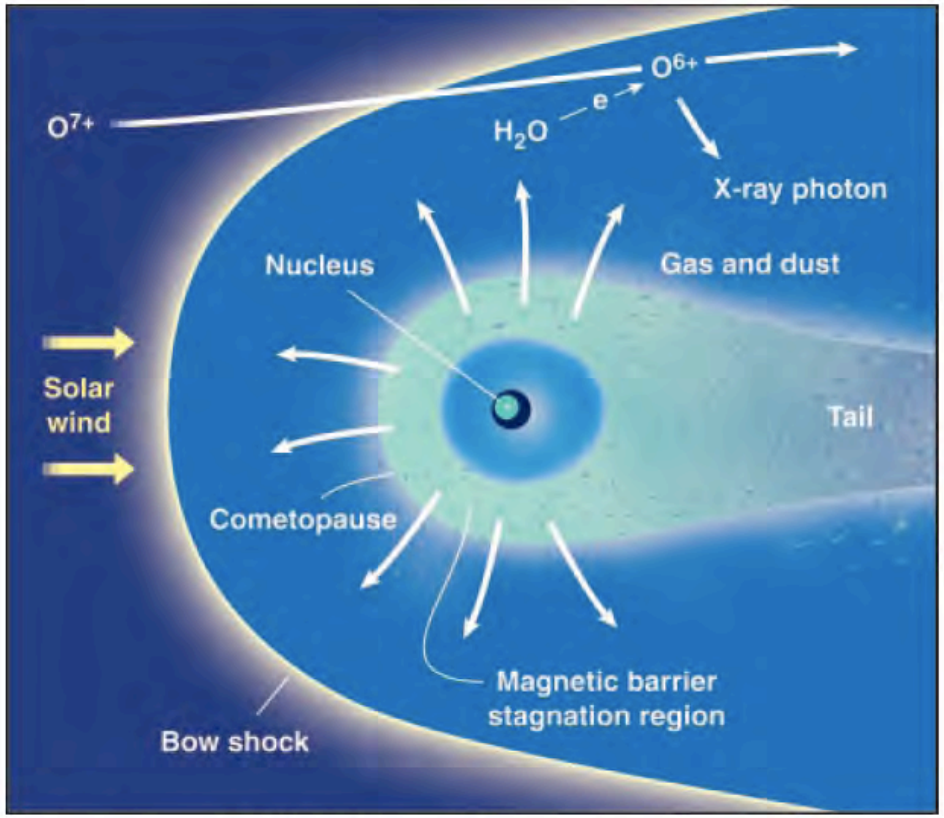
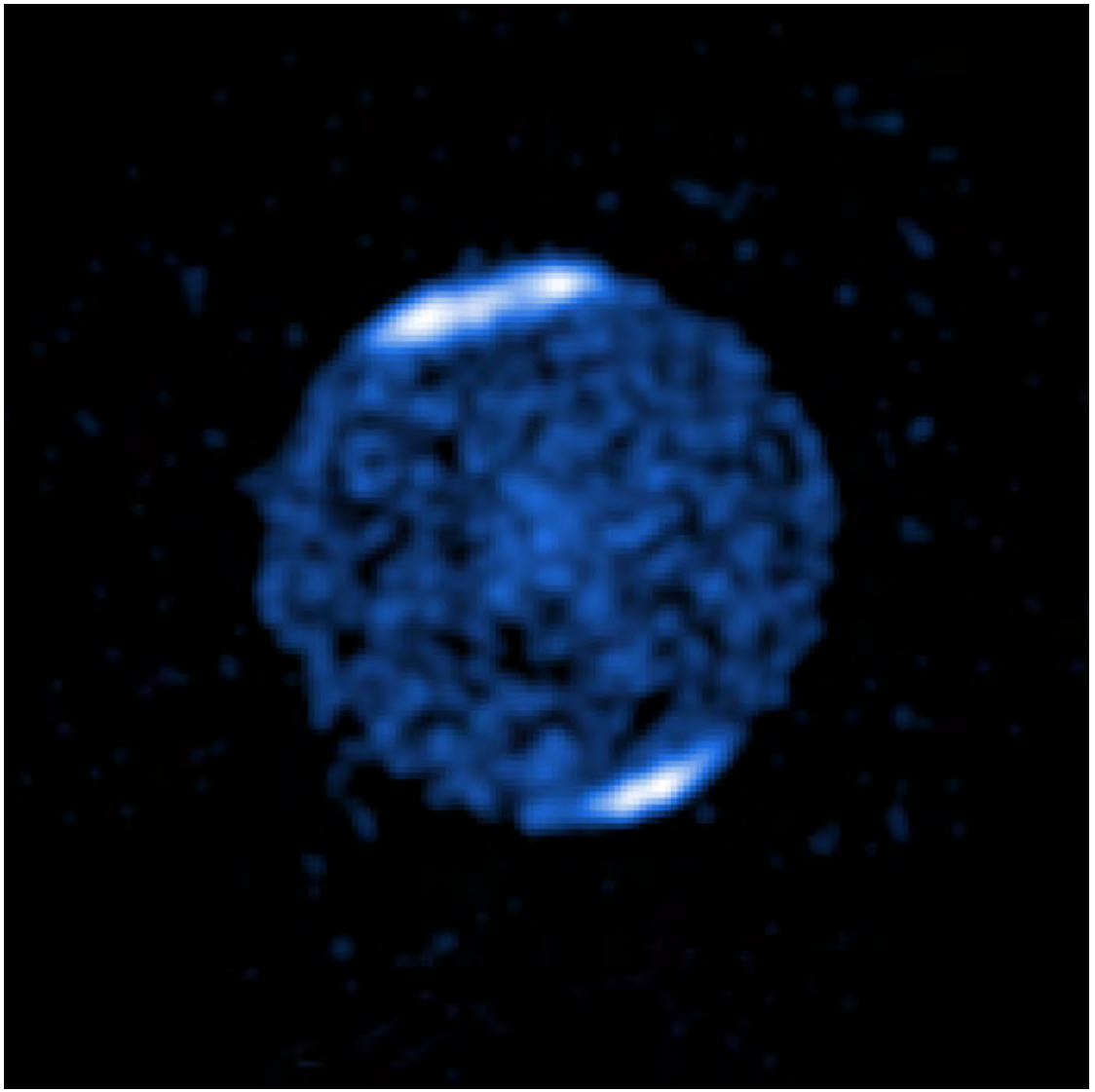
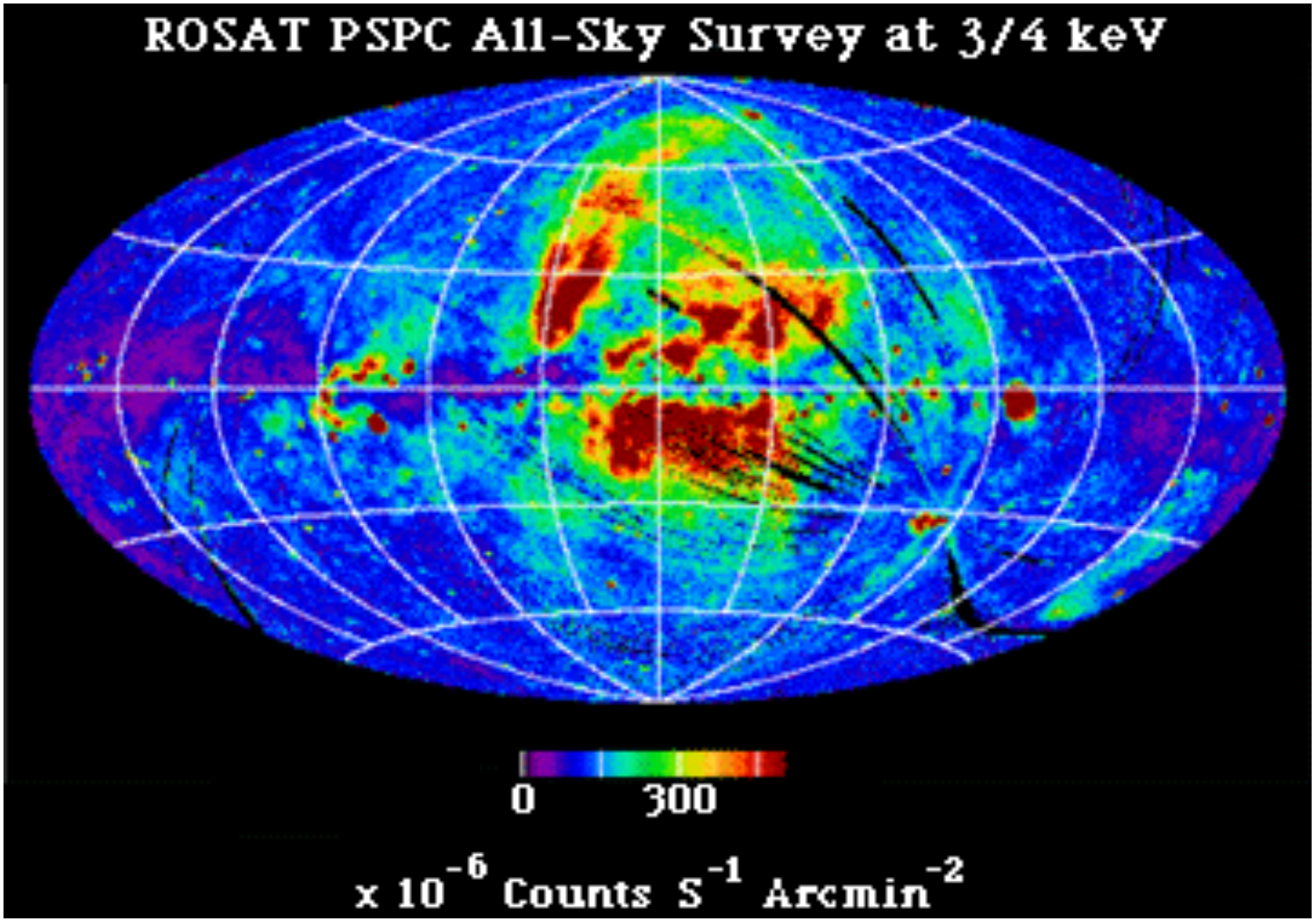


Fig. 3. Scheme of the solar wind/comet interaction. The location of the bow shock, magnetic barrier, and tail are shown. Also represented is a CT collision between a heavy solar wind ion and a cometary neutral water molecule, followed by the emission of an x-ray photon. The Sun is toward the left.



Chandra's image of Jupiter shows bright polar caps associated with auroral activity on Jupiter. X-ray spectra revealed that this activity is caused by highly charged ions of oxygen and other elements crashing into the atmosphere above Jupiter's poles.



Around 750 keV diffuse background map from the ROSAT all-sky survey.

Around 750 keV, the sky is dominated by the relatively smooth extragalatic background and a limited number of bright extended Galactic object.

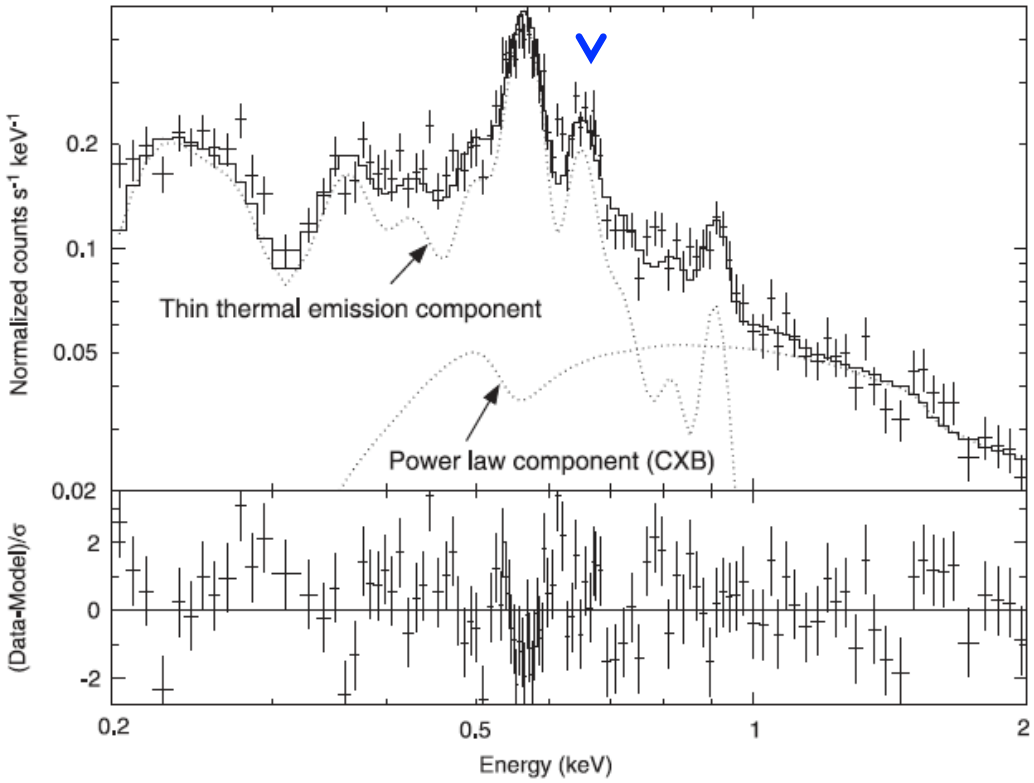
Suzaku (朱雀) the 5th Japanese X-ray astronomy satellite

(July 10, 2005 -)

The Soft X-ray background observed by Suzaku

O VII : $1s^2$-1s2p (560 eV)

O VIII : 1s-2p (653 eV)



Low energy resolution ~ 100 eV

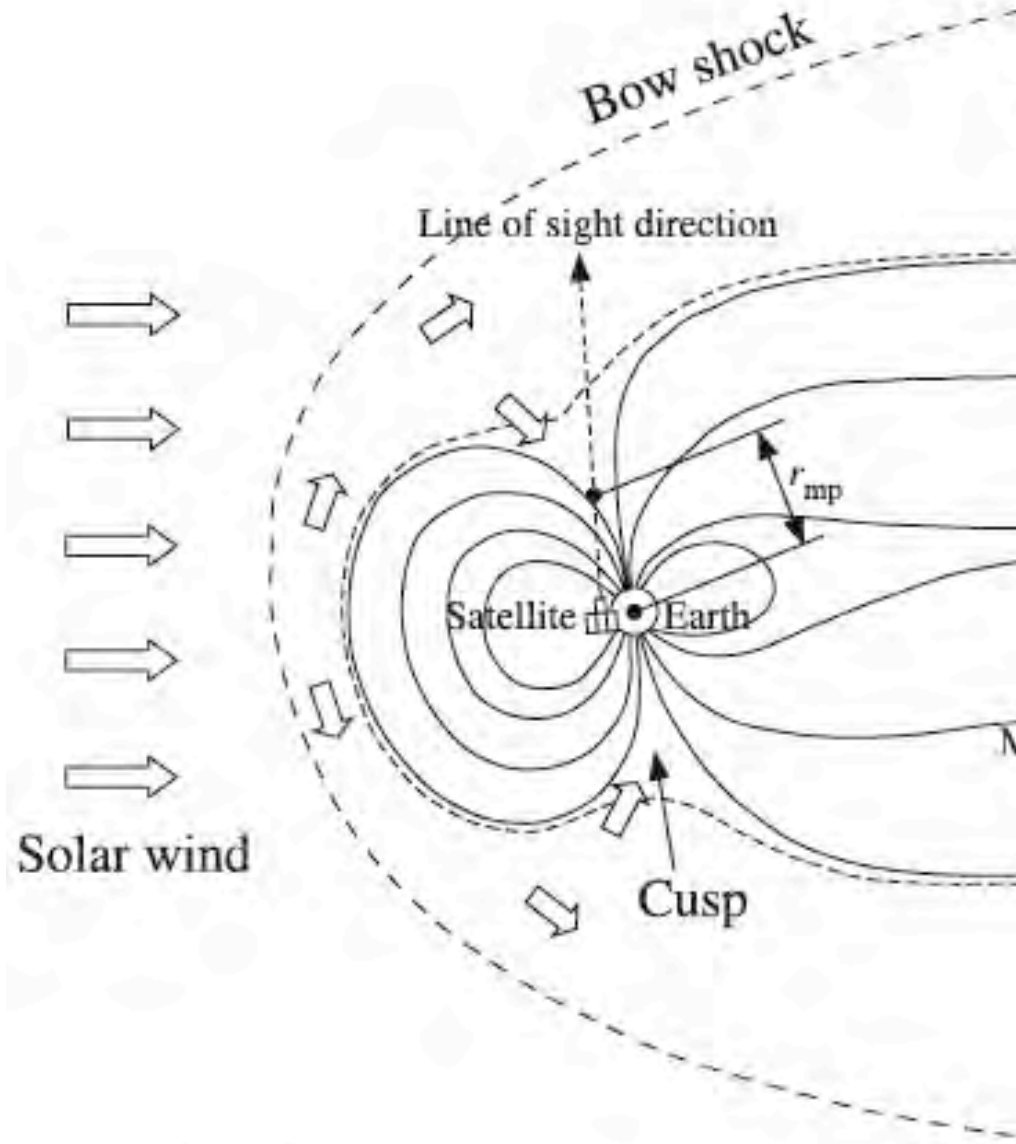


Fig. 8. Schematic view of the magnetos

Charge Exchange Madrid

29 September -1 October, 2010

European Space Astronomy Centre, Madrid, Spain

http://www.sciops.esa.int/index.php?project=CONF2010&page=CX2010

Collaboration with

Astrophysics Groups (TMU and JAXA)

who are working for the development of high energy resolution ($\Delta E < 5$ eV) TES micro-calorimeters

Goal : " High resolution CX spectra in soft X-ray using the TES micro-calorimeter "

$$ex. \quad O^{7+}(1s) + H \rightarrow O^{6+}(1snl) + H^{+}$$

$$\rightarrow O^{6+}(1s^2) + h\nu \ (\geq 561\text{eV})$$

Test measurements using Si(Li) detector

Some features of charge exchange collisions of multiply charges ions

- Very large cross sections ($> 10^{-16}$ cm^2)
- Single capture is usually dominant.
- Almost constant CS at keV range
- Increase/ decrease at very low energies
- Strong capture state selectivity
- Simple scaling rules for cross sections
- Emission lines are generally polarized.

Experimental setup (1)

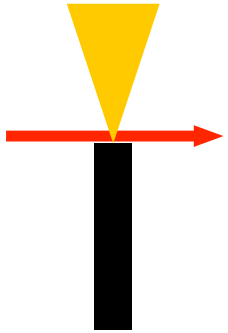
ECR ion source

Analyzing Magnet

aperture : Φ8

target gas
He, H_2

He, H_2 gas



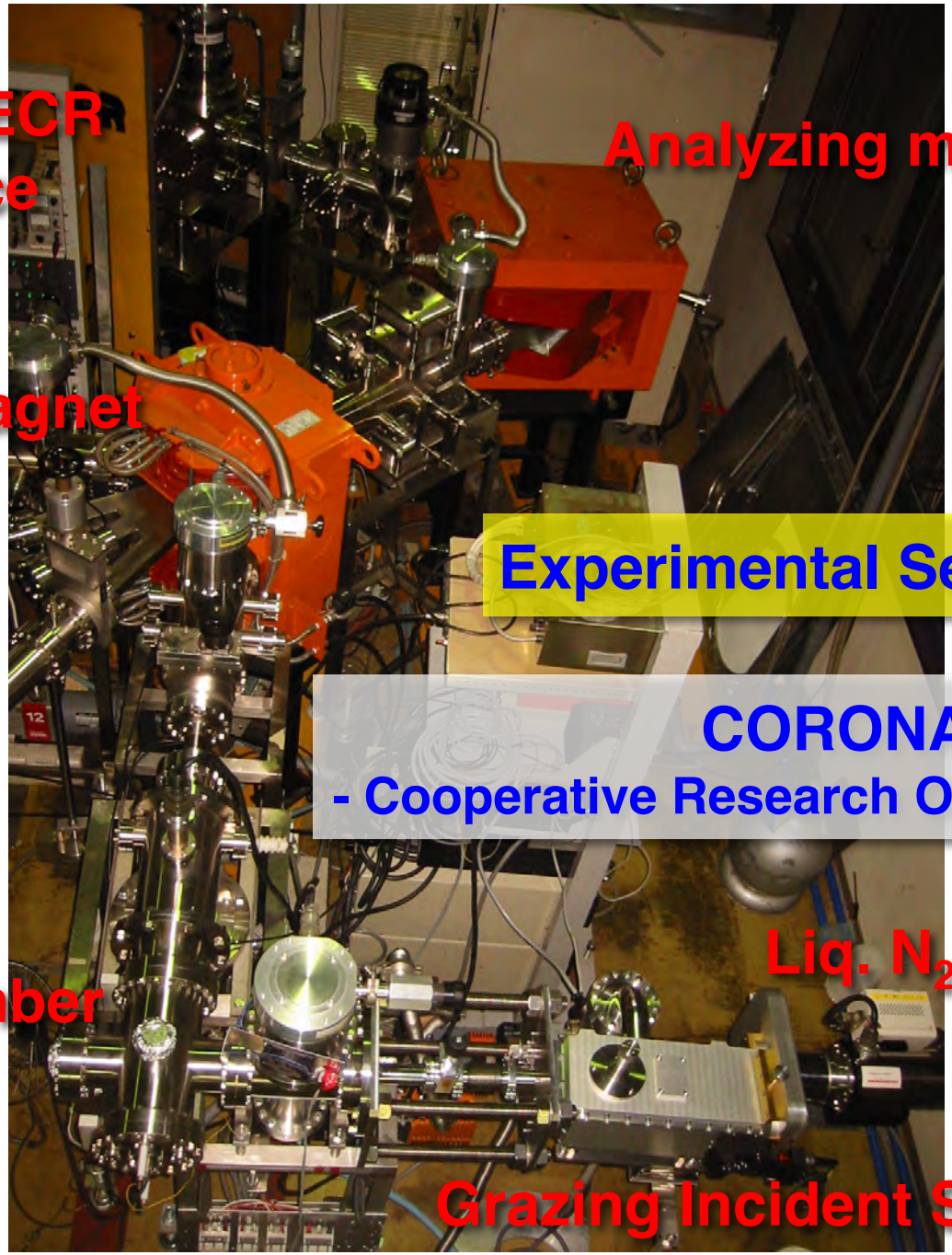
- Si(Li) detector (30mm^2)

Faraday cup

14.25 GHz ECR
ion source

Analyzing magnet

Switching magnet



Experimental Setup

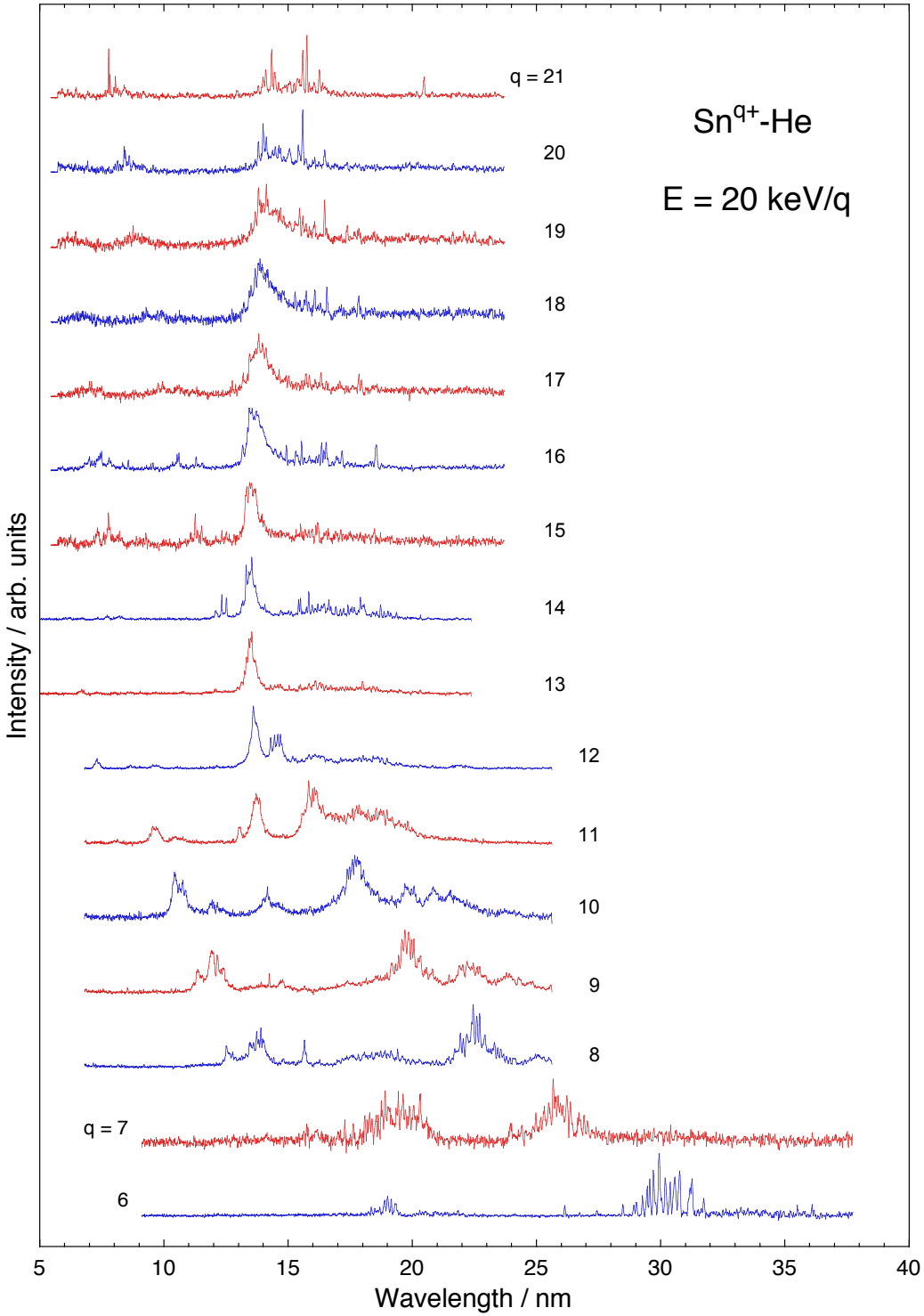
CORONA
- Cooperative Research On Novel Atoms -

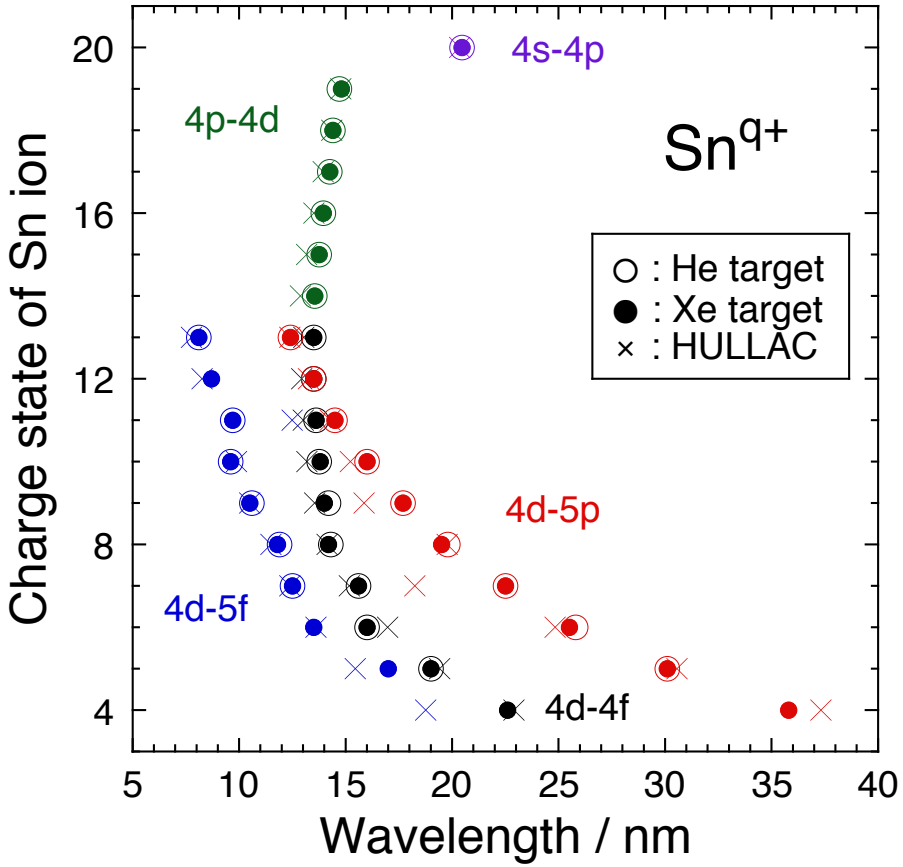
Liq. N_2 cooled CCD

Collision chamber

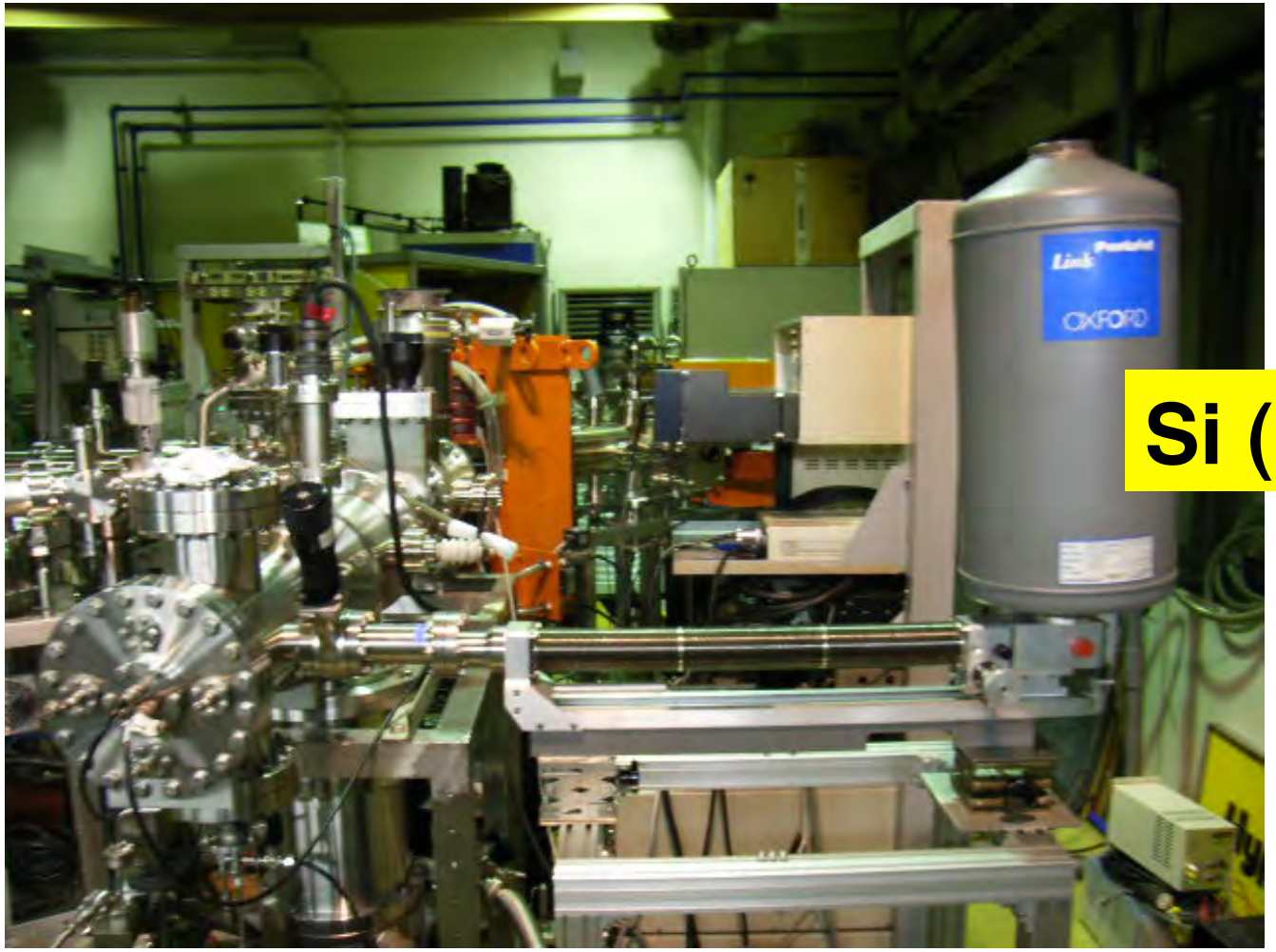
Grazing Incident Spectrometer

Summary of CXS experiments of Sn ions in TMU





Experimental setup (3)



Si (Li) detector

Window-less

ΔE = 160 eV@5.9 keV

$\Delta E \sim 107$ eV @ < 1 keV

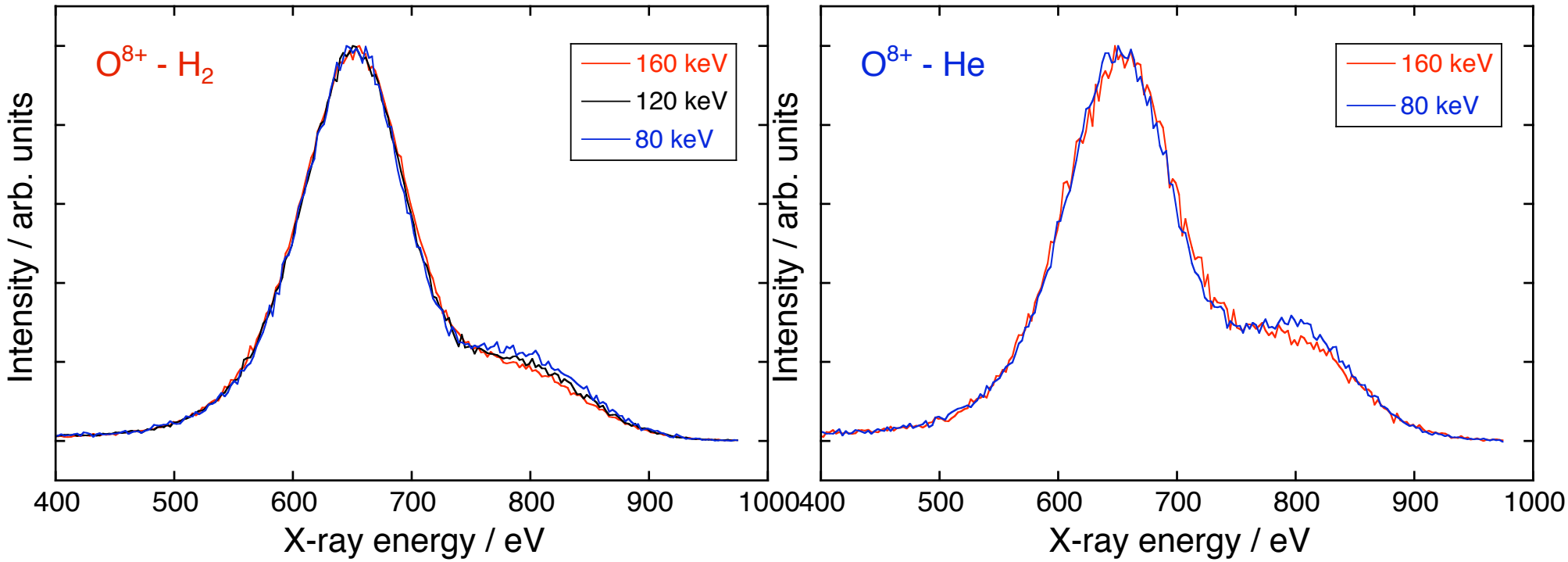
Preliminary

experimental spectra

in collisions of bare ions

with H_2 and He

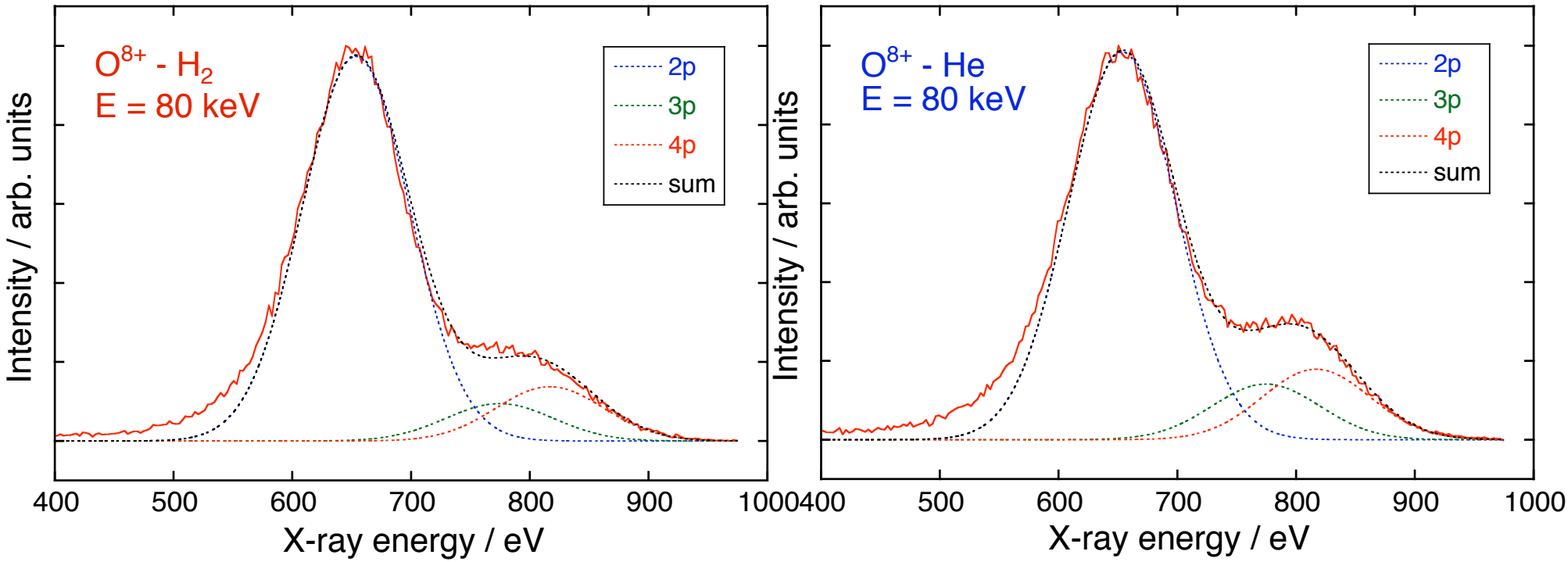
O^{8+} -H_2/He collisions (1)



Relative intensity of soft X-ray emission :

Collision energy dependence is small in the shape of spectrum.

O^{8+} -H_2/He collisions (2)



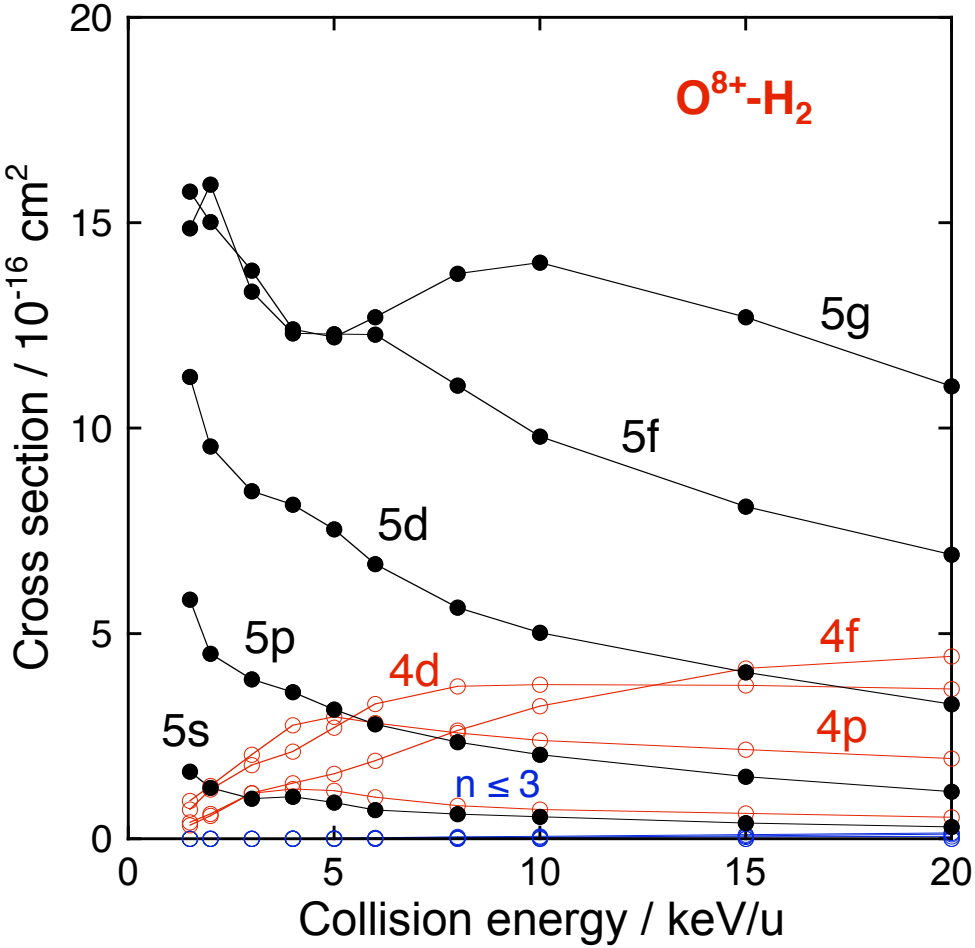
The 1s-2p transition is dominant.

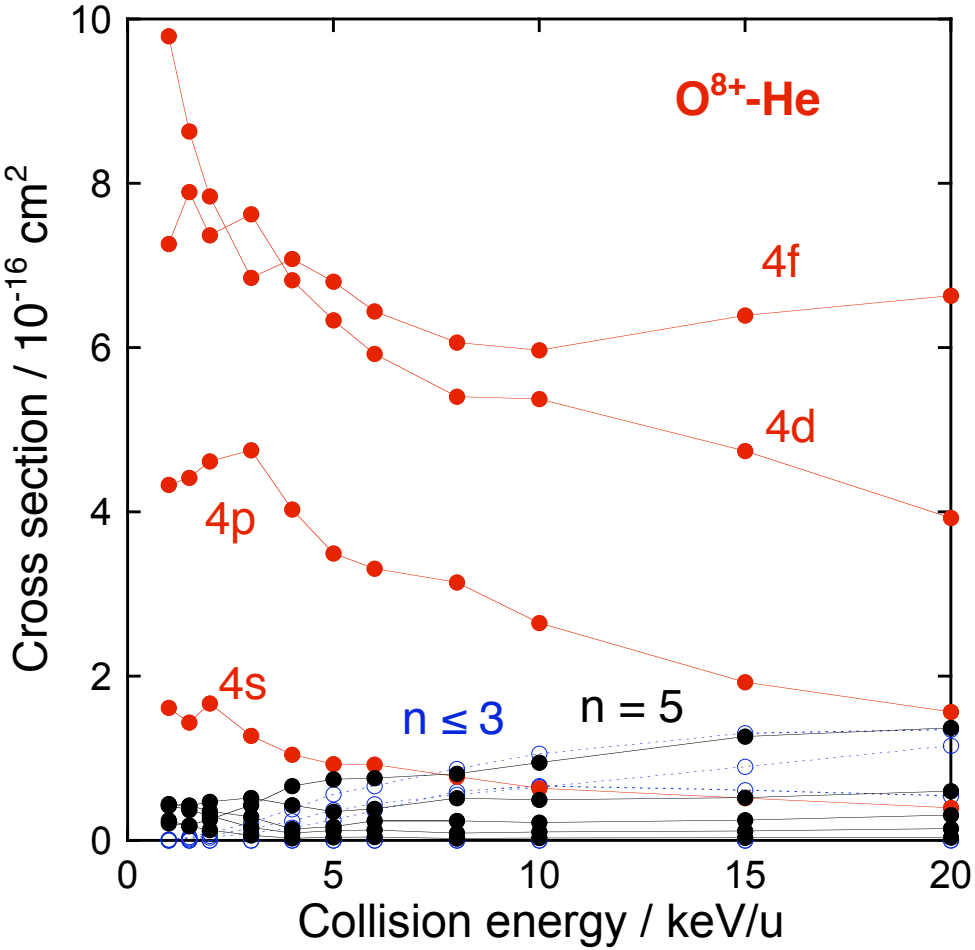
2p > 4p > 3p

2p > 4p > 3p

How to understand these spectra

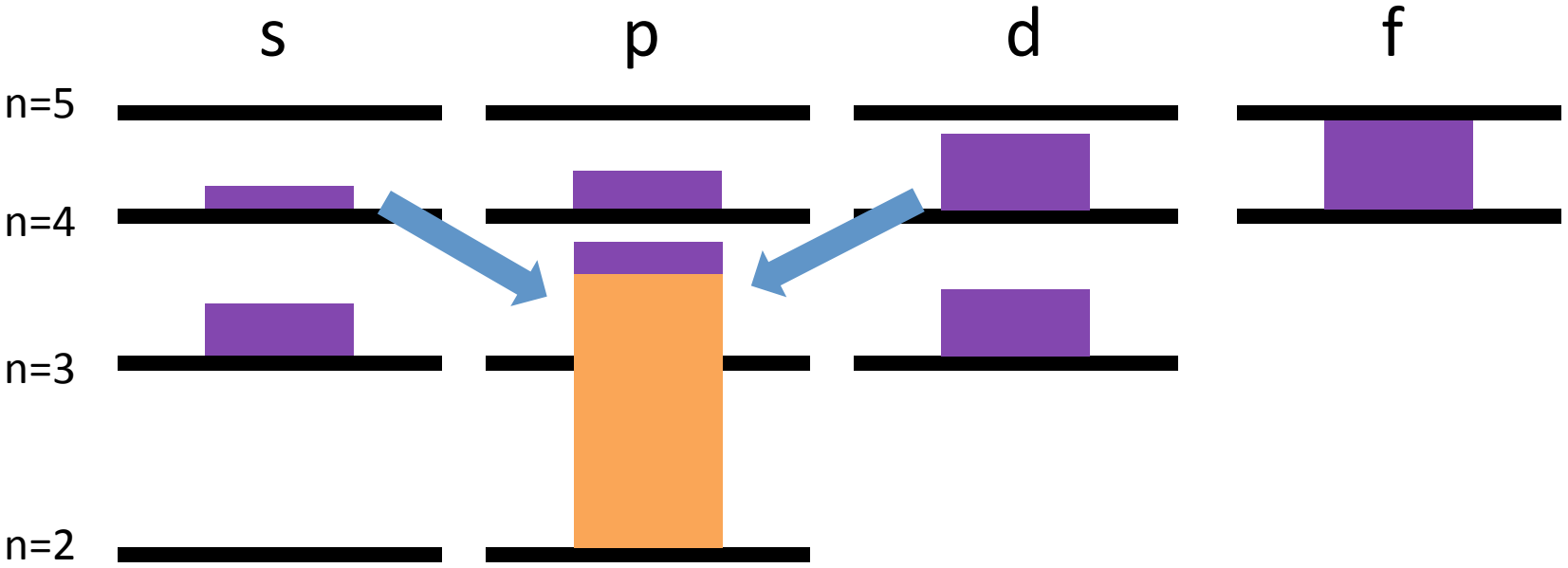
state-selective cross sections



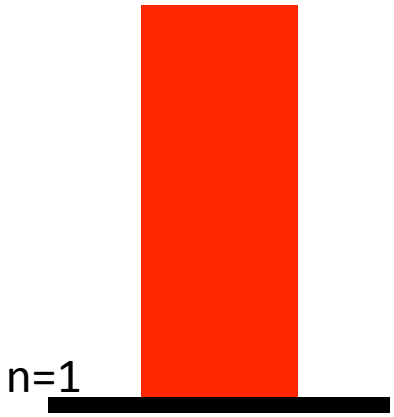


Ling LIU and Jianguo Wang (private communication)

Cascade of transitions



Initial state distribution

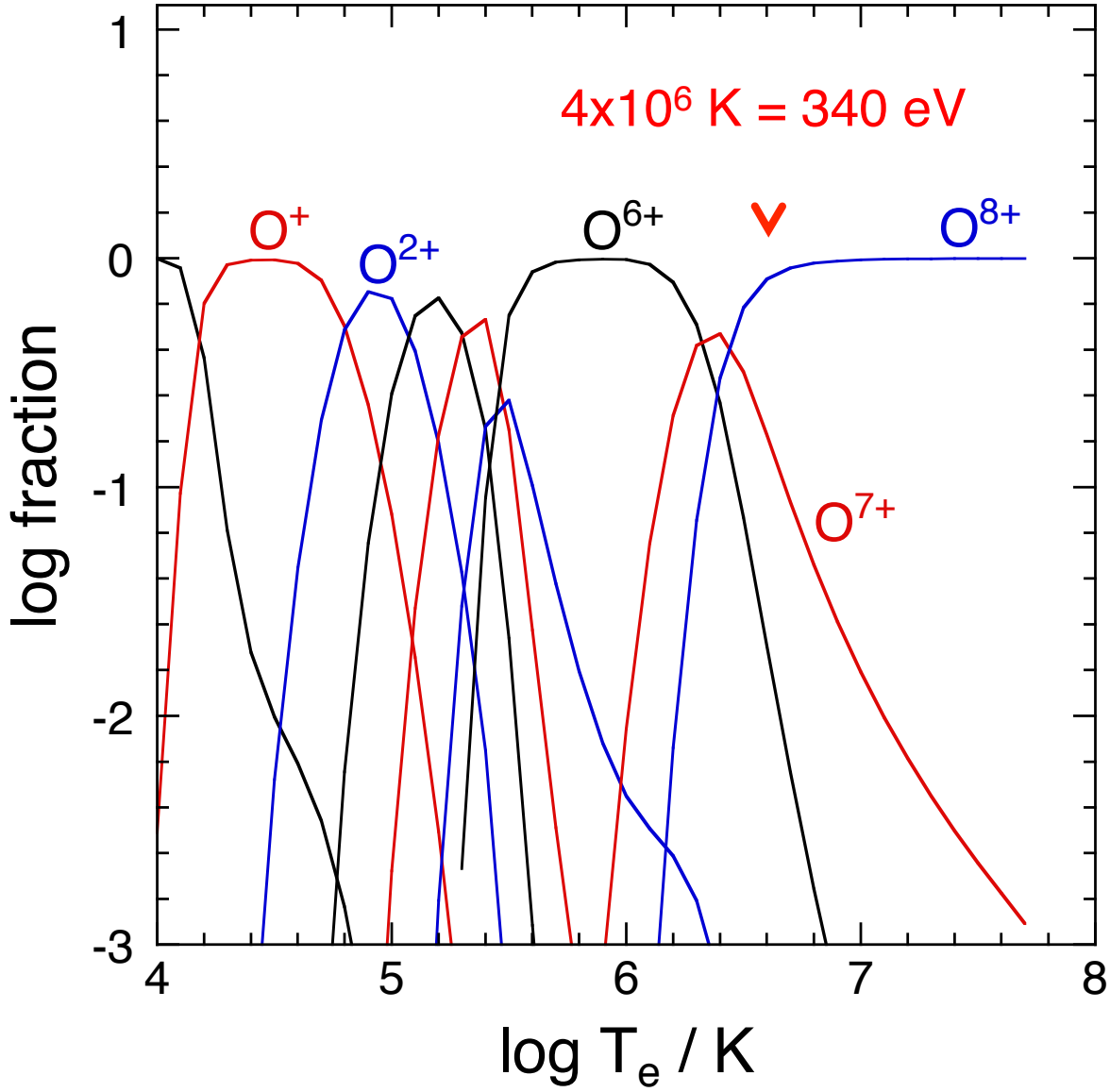


Proposal = Dream

- Extremely hot laser plasmas consist of bare ions and electrons.
- Charge exchange in the plasmas with puffed neutral gas will produce the 1s-2p emission with very strong intensity.
- ***Using the optimal structure of gas jets, lasers, and mirrors, is it possible to make a new type soft X-ray light source ?***
- O^{8+} + O_2, and N^{7+} + N_2 will not produce any debris.
- How about wavelengths ?

  O^{7+} : 1s-2p @ 1.897 nm, N^{6+} : 1s-2p @ 2.478 nm

Ion fraction as a function of electron temperature in oxygen plasmas



Collaborators

Atomic Physics Group in TMU

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Astrophysics Group in TMU

H. Akamatsu, Y. Ishisaki, and more staffs and students

JAXA / ISAS

K. Shinozaki, and K. Mitsuda

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L. Liu, and J-G. Wang

Thank you for your attention.

謝謝

御静聴ありがとうございました。